TRANSLATION CERTIFICATE

I, Mitsuru OBA, Oba & Associates, KM Building 8th Floor, 1-4-3, Iwamoto-cho, Chiyoda-ku, TOKYO 101-0032 JAPAN, hereby declare that I have competent knowledge of the Japanese and English languages, and that I have reviewed the translation of the Japanese Patent Application No. JP 2003-050167.

I certify that the translation is accurate.

CERTIFIED by the said Mitsuru OBA

at KM Building 8th Floor, 1-4-3, Iwamoto-cho, Chiyoda-ku, TOKYO 101-0032 JAPAN
October 5, 2005

Mitsuru OBA

[Document] Application for a Patent
[Docket Number] P-04916
[Filing Date] February 26, 2003
[To] Commissioner of the Patent Office
[International Patent Classification] B32B 15/00
H01F 1/00
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
[Name] Yasuo HASHIMOTO
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
[Name] Katsuhiko WAKAYAMA
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
[Name] Yasushi IIJIMA
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
[Name] Akira KAKINUMA
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
103-8272 Japan
[Name] Kazunori TASAKI
[Inventor]
[Address] (C/O) TDK Corporation
1-13-1, Nihonbashi, Chuo-ku, Tokyo
[Name] Tsutomu CHOU
[Patent Applicant]
[Identification Number] 000003067
[Name] TDK Corporation
[Agent]
[Identification Number] 100100077
[Patent Attorney]
[Name] Mitsuru OBA
[Fees]
[Account Number] 085823
[Amount of Payment] 21000 yen
[List of the articles]

[Article]	Specification	1
[Article]	Drawings	1
[Article]	Abstract	1
[Proof]	Yes	

[Document] Specification
[Title of the invention] SOFT MAGNETIC MEMBER
[Claims]
[Claim1] A soft magnetic member, comprising:
an insulating layer;
a metal sublayer disposed opposite to said insulating layer; and
a soft magnetic metal layer disposed on said metal sublayer,
wherein providing that the thickness of said metal sublayer is denoted by s and the thickness of said soft magnetic metal layer is denoted by p, then the relationships hold: $5 \leq p/s < 10$ and $0 < s < 100$ nm.
[Claim2] A soft magnetic member, comprising:
an insulating layer;
a metal sublayer disposed opposite to said insulating layer; and
a soft magnetic metal layer disposed on said metal sublayer,
wherein providing that the thickness of said metal sublayer is denoted by s and the thickness of said soft magnetic metal layer is denoted by p, then the relationships hold: $4 \leq p/s \leq 15$ and 100 nm $< s \leq 1000$ nm.
[Claim3] A soft magnetic member according to claim 1 or 2, wherein said metal sublayer is constituted by a material having a higher coercive force or a larger anisotropic magnetic field than said soft magnetic metal layer.
[Claim4] A soft magnetic member according to claim one of 1-3, wherein said soft magnetic metal layer is constituted by an alloy containing 20 to 80 wt % Fe, and one or two of Ni and Co.
[Claim5] A soft magnetic member according to claim one of 1-4, wherein a unit comprising said insulating layer, said metal sublayer and said soft magnetic metal layer is laminated in multiple layers.
[Detailed description of the invention]
[0001]
[Technical Field]
The present invention relates to a soft magnetic member wherein the real part of complex permeability is large and the imaginary part of complex permeability is small in a giga Hertz (GHz) band.
[0002]
[Prior arts]
Information and communications equipment tends to become smaller in size and the frequency band is shifting to the high frequency side. So far, high performance design of electronic parts utilizing permittivity has been carried out. On the other hand, in a case where efficiency is to be improved by utilizing electromagnetic waves in near-field, high performance design utilizing permeability can be expected. In the prior arts, because the permeability of magnetic materials in a GHz band shows smaller values by one digit than the permeability in a band of lower frequency, permeability has not hitherto been utilized in a positive manner and

dielectrics have been exclusively used in high frequency related parts. However, in high frequency related parts including antennas, limitations to the improvement of properties by using permittivity have appeared and it is difficult to expect dramatic improvements in efficiency.

[0003]

On the other hand, research to improve permeability in high frequencies such as a GHz band is also being pushed forward with.

For example, it is known that a multilayer film having a structure formed by alternately depositing a magnetic material layer and a nonmagnetic material layer (SiO_2) on a substrate by the ion beam sputtering shows excellent complex permeability in a GHz band (Senda, Nagai, Ishii and Michikami, NTT R&D, Vol. 42, No. 5 (1993), pp. 689-696). In this case, in order to realize high permeability, the smaller magnetostriction, the more advantageous. For this reason, there has been proposed, for example, a magnetic material layer in which magnetostriction is controlled to low levels by causing Fe (magnetostriction: negative) and an NiFe alloy (magnetostriction: positive) to diffuse mutually. Also, a film of small magnetostriction, such as a CoNbZr film, is subjected to a heat treatment in a magnetic field, thereby imparting induction anisotropy to the film, so that high permeability is maintained even in high frequency band such as a GHz band. Incidentally, anisotropy can be imparted also by forming a fine pattern in addition to performing a heat treatment in a magnetic field (Suezawa, Yamaguchi, Arai, Shimada, Tanabe and Ito, the Journal of Japan Society for Applied Magnetics, Vol. 24 (2000), pp. 731-734).

[0004]

[Non-Patent Document 1] NTT R&D, Vol. 42, No. 5 (1993), pp. 689-696

[Non-Patent Document 2] The Journal of Japan Society for Applied Magnetics, Vol. 24 (2000), pp. 731-734

[0005]

[Problems to be Solved by the Invention]

In the above-described techniques for increasing permeability in a GHz band involve increasing an anisotropic magnetic field thereby shifting to a higher frequency side by depositing a soft magnetic film on a substrate and thereafter imparting induction anisotropy to the soft magnetic film by subjecting the film to a heat treatment in a magnetic field or imparting shape anisotropy by forming a fine pattern. However, in the above-described techniques, it is necessary to use a hard substrate material and furthermore in order to impart anisotropy, it is necessary to perform an expensive heat treatment and work. Therefore, shape and price restrictions are severe and form a bottleneck in practical application.

The present invention was made on the basis of such technical problems and the subject is to provide a soft magnetic member which is easily produced, together with exhibits high permeability in a GHz band.

[0006]

[Means for Solving the Problem]

Referring to the subject, the present invention is a soft magnetic member, comprising: an insulating layer; a metal sublayer disposed opposite to said insulating layer; and a soft magnetic metal layer disposed on said metal sublayer, wherein providing that the thickness of said metal sublayer is denoted by s and the thickness of said soft magnetic metal layer is denoted by p, then the relationships hold: $5 \leq p/s < 10$ and $0 < s < 100$ nm.

Further, the present invention is a soft magnetic member, comprising: an insulating layer; a metal sublayer disposed opposite to said insulating layer; and a soft magnetic metal layer disposed on said metal sublayer, wherein providing that the thickness of said metal sublayer is denoted by s and the thickness of said soft magnetic metal layer is denoted by p, then the relationships hold: $4 \leq p/s \leq 15$ and $100 \text{ nm} < s \leq 1000$ nm.

[0007]

In the soft magnetic member of the present invention, it is desirable that the metal sublayer is constituted by a material having a higher coercive force or a larger anisotropic magnetic field than the soft magnetic metal layer.

Further, in the soft magnetic member of the present invention, it is desirable that the soft magnetic metal layer is constituted by an alloy containing 20 to 80 wt % Fe, and one or two of Ni and Co.

Furthermore, the soft magnetic member of the present invention includes an embodiment in which a unit comprising said insulating layer, said metal sublayer and said soft magnetic metal layer is laminated in multiple layers.

[0008]

[Embodiments of the invention]

The present invention will be described below in detail based on embodiments shown in drawings.

FIG. 1 is a partial sectional view showing an example of construction of a soft magnetic member of the present invention.

A soft magnetic member 1 shown in FIG. 1 is constituted by a resin film 2, a metal sublayer 3 formed on the resin film 2 and a soft magnetic metal layer 4 formed on the metal sublayer 3.

As the resin film 2 which functions as an insulating layer, Polyethylene, polypropylene, polystyrene, melamine resin, urea resin, phenol resin, polyethylene terephthalate, polybutylene terephthalate, polysulfone, polycarbonate, polytetrafluorethylene, polyamide-imide, polyamide, polyolefin, polyimide, PPS (polyphenylenesulfide), fluoroplastics and silicone resin can be used. Among these, it is desirable to use resin materials having heat resistance when a heat treatment is performed in the manufacturing process of a laminated soft magnetic member, as will be described later.

[0009]

The soft magnetic metal layer 4 can be constituted by any of the transition metal elements exhibiting magnetism or any of the alloys of transition metal elements and other metal elements. As concrete examples, such alloys are those which contain, as a main component, one or two elements of Fe, Ni and Co, and they are Fe-Ni based alloys, Fe-Co based alloys, Fe-Ni-Co based alloys and Co-Ni based alloys. Among these, it is desirable to use alloys having a saturation flux density of 1.0 T or greater and, preferably, of 1.5 T or greater. Among these, it is especially desirable to use Fe-Ni alloys, Fe-Co alloys and Fe-Ni-Co alloys having an Fe content of 20 to 80 wt % (preferably, 30 to 70 wt %, more preferably, 40 to 65 wt %). Alloys having such a composition are high in saturation flux density, and are advantageous in that the resonance frequency is shifted to the higher frequency side by increasing the anisotropic magnetic field through anisotropy control. These alloys can contain 15 at% or less of one or more of Nb, Mo, Ta, W, Zr, Mn, Ti, Cr, Cu and Co. Incidentally, when a soft magnetic metal layer 4 is formed by plating (electrolytic or non-electrolytic), such elements as C and S are inevitably contained, and the soft magnetic metal layer 4 of the present invention allows the presence of such elements contained.

[0010]

As for the soft magnetic metal layer 4, either a crystalline alloy or an amorphous alloy can be used. As an amorphous alloy, Co based amorphous alloys and Fe based amorphous alloys can be used. Additionally, the present invention allows the use of Fe based microcrystalline alloys. A microcrystalline alloy is generally known as an alloy which is mainly composed of fine crystals of about 10 nm in grain size.

The soft magnetic metal layer 4 can be produced by a variety of film formation processes including the plating, vacuum evaporation method, sputtering method and the like. These film formation processes can be applied each alone. Accordingly, the soft magnetic metal layer 4 can be formed either solely by plating or solely by evaporation. Needless to say, a plurality of film formation processes can be combined. Plating is preferable for the present invention in that plating can form films at lower temperatures than the vacuum evaporation method. Especially in the case that the soft magnetic metal layer 4 is formed on a resin film, this is because it is preferable that no thermal effect is given to the resin film 2. Additionally, plating has a merit that plating can obtain a prescribed thickness of film in a shorter period of time as compared to the sputtering method. Incidentally, when the soft magnetic metal layer 4 is obtained by plating, some elements such as S contained in the plating bath are mixed in the soft magnetic metal layer 4, and hence the soft magnetic metal layer 4 formed by plating is discriminable from the soft magnetic metal layers 4 formed by the other processes.

[0011]

For the metal sublayer 3, it is desirable to select a material having a higher

coercive force (anisotropic magnetic field) than the soft magnetic metal layer 4. By doing so, it is possible to increase the anisotropic magnetic field of the soft magnetic metal layer 4, thereby to increase the ferromagnetic resonance frequency in a GHz band. As a result, it is possible to increase the μ' (real part of complex permeability) in the vicinity of 2 GHz and simultaneously to reduce μ'' (imaginary part of complex permeability). In the frequency bands used in portable communications equipment, the larger μ' and the smaller μ'', the higher an effect on the radiation efficiency improvement of electromagnetic waves will be. Incidentally, an effect on the permeability improvement in a GHz band can also be expected by forming a layer composed of a material similar to that of the metal sublayer 3 on the soft magnetic metal layer 4. When the soft magnetic metal layer 4 is an Fe-Ni alloy, it is desirable to use pure Ni as the metal sublayer 3.

[0012]

Although the metal sublayer 3 serves to enhance the anisotropic magnetic field of the soft magnetic metal layer 4, the metal sublayer 3 also plays a role of a conductive layer becoming necessary when the soft magnetic metal layer 4 is formed by electrolytic plating on the resin film 2. The metal sublayer 3 can be formed, for example, by the vacuum evaporation method, sputtering method or non-electrolytic plating.

[0013]

Next, the thickness of the soft magnetic member 1 will be described.

The thickness of the resin film 2 should be 50 μm or less. Although the resin film 2 functions as a substrate of the soft magnetic member 1, the resin film 2 also carries out the function of mutual insulation of the soft magnetic metal layers 4 when the soft magnetic member 1 is laminated. However, if this insulating layer becomes thick, the packing density of the soft magnetic metal layer 4 decreases and hence the permeability of the soft magnetic member 1 decreases. Therefore, the thickness of the resin film 2 should be 50 μm or less. The preferable thickness of the resin film 2 is 25 μm or less and the more preferable thickness of the resin film 2 is 10 μm or less. As a matter of course, it is difficult to manufacture an extremely thin resin film 2 and, at the same time, it is impossible to have a predetermined strength necessary for forming the soft magnetic metal layer 4. Therefore, it is recommended that the thickness be 0.2 μm or more, or 2 μm or more. Incidentally, because the resin film 2 used in the present invention has flexibility, handling is easy when the soft magnetic member 1 including it is installed in various types of equipment.

[0014]

It is preferred that the soft magnetic metal layer 4 be 1 μm or less in thickness. Incidentally, the thickness of the soft magnetic metal layer 4 is hereinafter denoted by p. This is because in thicknesses exceeding it, eddy current losses are large in a high frequency band exceeding 800 MHz which is a target of the present invention and hence the function as a magnetic material deteriorates.

Therefore, p is more preferably 0.5 μm or less. Because it is desirable that the soft magnetic metal layer 4 be densely formed, it is necessary that the soft magnetic metal layer 4 has a minimum film thickness of such an extent that enables a dense film to be formed by various processes. Incidentally, an oxide film may be formed on the surface of the soft magnetic metal layer 4.

[0015]

In order to ensure that the metal sublayer 3 functions to improve the anisotropic magnetic field of the soft magnetic metal layer 4 and also functions as a conductive layer during electrolytic plating, the thickness of the metal sublayer 3 should be 100 nm or less when it is used in a high frequency band exceeding 800 MHz. Incidentally, the thickness of the metal sublayer 3 is hereinafter denoted by s. A preferable s for a use in a high frequency band exceeding 800 MHz is 80 nm or less, and a more preferable film thickness s is 50 nm or less.

Incidentally, between the metal sublayer 3 and the resin film 2, for example, a metal oxide layer or an adhesive layer may be interposed. Also, on the surface of the metal sublayer 3, i.e., between the metal sublayer 3 and the soft magnetic metal layer 4, a metal oxide layer may be present. The interposition of a metal oxide layer which is large in electric resistance weakens the magnetic coupling between the metal sublayer 3 and the soft magnetic metal layer 4 a little, but increases the electric resistance along the film cross section direction and provides an effect which reduces the eddy current. If the thickness of the metal oxide layer is too large, plating becomes difficult. Therefore, the thickness of the metal oxide layer should be 40 nm or less and is preferably 20 nm or less, more preferably 10 nm or less. This metal oxide layer can be formed by exposing the metal sublayer 3 to the air after completion of the metal sublayer 3 formation. This is also the case for the metal oxide film formed on the surface of the soft magnetic metal layer 4.

[0016]

The thickness s of the metal sublayer 3 and the thickness p of the soft magnetic metal layer 4 were described, the ratio between s and p (p/s) is important in the present invention, because p/s effects a magnetic coupling between the soft magnetic metal layer 4 and the metal sublayer 3. More specifically, if p/s is too small, the properties of the imaginary part of complex permeability (μ'') becomes broad or shows double peak and tan δ ($= \mu''/\mu'$, μ' : the real part of complex permeability) becomes large, and this is undesirable. On the other hand, if p/s is too large, the frequency properties of μ'' shows a single peak and the band also becomes narrow. However, the frequency at which μ' begins to attenuate decreases and the permeability in a GHz band deteriorates. Although p/s depends on the thickness and material quality of the soft magnetic metal layer 4 and metal sublayer 3, the range of p/s should be $5 \leq p/s < 10$ and is preferably $6 \leq p/s \leq 8$.

[0017]

In the soft magnetic member 1 shown in FIG. 1, the metal sublayer 3 and the soft magnetic metal layer 4 are formed on one side of the resin film 2. In the

present invention, it is also possible to form the metal sublayer 3 and the soft magnetic metal layer 4 on both front and back sides of the resin film 2.

Although FIG. 1 shows an example in which the resin film 2 is used as an insulating layer, the present invention does not exclude the use of materials other than the resin film 2. For example, ceramics materials can also be used as an insulating layer.

[0018]

In the present invention, the soft magnetic member 1 can be used singly and it is also possible to use a plurality of laminated soft magnetic members 1. A member in which the soft magnet member 1 is laminated in multiple layers as one unit is hereinafter referred to as a laminated soft magnetic member.

FIG. 2 is a sectional view showing an example of a laminated soft magnetic member 20 according to this embodiment. As shown in FIG. 2, the laminated soft magnetic member 20 has a sectional structure in which a resin film 2, a metal sublayer 3 and a soft magnetic metal layer 4 are alternately laminated. It is important that the thickness of the whole laminated soft magnetic member 20 be 0.2 mm or less. This is because when the laminated soft magnetic member 20 in sheet form is applied to a cellular phone, it is necessary that the laminated soft magnetic member 20 adapt to the size of the cellular phone. A more preferable thickness is 0.15 mm or less and a still more preferable thickness is 0.1 mm or less. Incidentally, the laminated soft magnetic member 20 may include a portion in which the lamination order of a unit comprising the resin film 2, the metal sublayer 3 and the soft magnetic metal layer 4 differs.

[0019]

By laminating the soft magnetic member 1 shown in FIG. 1, the laminated soft magnetic member 20 can be obtained.

Because the resin film 2 of the soft magnetic member 1 constitutes an insulating layer, the thickness of the insulating layer becomes 50 μm or less. As a matter of course, in some cases the insulating layer becomes thicker than that of the resin film 2 when an adhesive is interposed between layers in laminating the soft magnetic member 1. Therefore, when an adhesive is used, it is necessary to determine the thickness of the resin film 2 so that the thickness of the insulating layer becomes 50 μm or less. If an adhesive is formed from a resin at this time, it follows that also the adhesive layer constitutes the insulating layer. Incidentally, it is possible to provide an insulating layer on the soft magnetic metal layer 4 which is positioned at the uppermost layer, so that the soft magnetic metal layer 4 is not exposed to the outside.

Additionally, a sticking agent or a double coated adhesive tape can be applied to either of the surfaces of the laminated soft magnetic member 20. This is for the sake of convenience in the application of the laminated soft magnetic member 20 to appliances such as cellular phones.

[0020]

A preferred manufacturing method for obtaining the laminated soft magnetic member 20 will be described below on the basis of FIG. 3.

First, in FIG. 3, a metal sublayer 3 is formed on a resin film 2 by the vacuum evaporation method, for example (FIG. 3(a)).

By forming a soft magnetic metal layer 4 on the metal sublayer 3 by electrolytic plating, for example, after the formation of the metal sublayer 3, it is possible to obtain the soft magnetic member 1 shown in FIG. 1 (FIG. 3(b)).

A prescribed number of the soft magnetic members 1 are produced, the members are laminated in such a way that the resin films 2 and the soft magnetic metal layers 4 of the respective soft magnetic members 1 are made to face each other, and thus the laminated soft magnetic member 20 shown in FIG. 2 can be obtained (FIG. 3(c)).

[0021]

The bonding of the soft magnetic members 1 together can be performed by disposing an adhesive of epoxy resin, silicone resin, etc., for example, between the soft magnetic members 1. The viscosity of an adhesive should be 1000 cP or lower and is preferably 300 cP or lower, more preferably 200 cP or lower. An adhesive to which a solvent has been added is applied to the soft magnetic member 1, the solvent is then caused to evaporate to such an extent that the adhesive maintains adhesion properties, and thereafter the soft magnetic members 1 are laminated. Due to the static electricity of the resin film 2 which composes the soft magnetic member 1, it is also possible to maintain the laminated condition without using an adhesive. In this case, after the soft magnetic members 1 have been laminated, only the outer peripheral portion thereof can be subjected to adhesive bonding for the purpose of improving the adhesion strength by immersing the laminated members into an adhesive. Furthermore, because an adhesive layer functions as an insulating layer, laminating may be performed, with the soft magnetic metal layers 4 opposed to each other or with the resin films 2 opposed to each other.

[0022]

By performing stress relief annealing after obtaining the laminated soft magnetic member 20, it is also possible to improve the magnetic properties. For example, when an adhesive is used in bonding the soft magnetic members 1 together, a stress relief annealing can also be performed in such a manner as to serve as a heat treatment for drying the adhesive. When a stress relief annealing is performed, it is desirable to use for the resin film 2 polyamide-imide resin, polyamide resin, polyimide resin or PPS (polyphenylenesulfide) resin since they are excellent in heat resistance.

Furthermore, when PET (polyethylene terephthalate) or PBT (polybuthylene terephthalate) is used for the resin film 2, it is also possible to improve the magnetic properties by imparting induction anisotropy by use of contraction stresses by heating.

Additionally, the laminated soft magnetic member 20 can be processed into a desired shape by the warm press processing. Furthermore, the laminated soft magnetic member 20 can be processed by cutting into a desired size.

[0023]

Next, another manufacturing method for obtaining the laminated soft magnetic member 20 will be described on the basis of FIG. 4.

In the FIG. 4, a metal sublayer 3 is formed on a resin film 2 by the vacuum evaporation method, for example (FIG. 4(a)). A soft magnetic metal layer 4 is formed on the metal sublayer 3 by electrolytic plating, for example, after the formation of the metal sublayer 3 (FIG. 4(b)). These steps are the same as in the manufacturing method shown in FIG. 3.

Next, a resin layer 5 for heat fusion bonding is formed on the soft magnetic metal layer 4 (FIG. 4(c)). The formation of the resin layer 5 can be performed by various techniques of coating, spraying, etc.

By peeling and removing the resin film 2 after the formation of the resin layer 5, a soft magnetic member 10 in which the metal sublayer 3, the soft magnetic metal layer 4 and the resin layer 5 are laminated is obtained (FIG. 4(d)). The peeling of the resin film 2 can be relatively easily performed by making the adhesive strength of the resin layer 5 with respect to the soft magnetic metal layer 4 higher than the adhesive strength of the resin film 2 with respect to the metal sublayer 3.

[0024]

A prescribed number of the soft magnetic members 10 are produced, the members are laminated in such a way that the resin layers 5 and the soft magnetic metal layers 4 of the respective soft magnetic members 10 are made to face each other, and thus the laminated soft magnetic member 20 can be obtained (FIG. 4(e)).

Bonding the soft magnetic members 10 together can be performed by use of the resin layers 5. That is, laminating is performed, with the resin layers 5 and the soft magnetic metal layers 4 of the respective soft magnetic members 10 facing each other, and thereafter the resin layers 5 are fused and cured by a prescribed heat treatment, which can ensure the mutual adhesion strength between the adjacent soft magnetic members 10. Additionally, although FIG. 4 show an example in which the plurality of the soft magnetic members 10 are produced and then laminated, needless to say it is also possible to obtain a winding body in such a way that the peeling off of the resin film 2 and the formation of the resin layer 5 are conducted consecutively, and the sheet body is subjected to winding.

Incidentally, although in the above description the soft magnetic members 10 are bonded through heat fusion bonding of the resin layers 5, the soft magnetic members 10 can be bonded through thermo-compression of the resin layers 5. For instance, the soft magnetic members 10 can be mutually bonded with the aid of the thermo-compression bonded resin layers 5, on the basis of the selection of PET for the resin layer 5 and the application of a prescribed pressure under the condition of being heated to a temperature of about 150 to 300°C.

[0025]

Although the above descriptions were given on the assumption that the soft magnetic member 1 (10) of the present invention is used in a high frequency band exceeding 800 MHz, the soft magnetic member 1 (10) of the present invention can also be used in a frequency band of 800 MHz or lower, for example, in the vicinity of 100 MHz. In this case, however, the thickness of the metal sublayer 3 should exceed 100 nm. This is because the magnetic coupling with the soft magnetic metal layer 4 becomes weak if the thickness of the metal sublayer 3 is 100 nm or less. However, if the thickness exceeds 1000 nm, the thickness is too large and the superiority as the soft magnetic member 1 (10) is lost. Therefore, on the assumption that the soft magnetic member 1 (10) is used in the above-described frequency band, the thickness (s) of the metal sublayer 3 should be 100 nm to 1000 nm (not including 100 nm). A preferable thickness s is 110 nm to 700 nm and a more preferable thickness s is 110 nm to 500 nm.

[0026]

When the thickness (s) of the metal sublayer 3 is in the above-described range, the magnetic effect of the metal sublayer 3 thickness on the soft magnetic metal layer 4 becomes large. Therefore, p/s should be 4 to 15. Excellent complex permeability can be obtained in this range. If p/s is less than 4, the control effect by the metal sublayer 3 on an anisotropic magnetic field becomes small and high permeability cannot be obtained. And, if p/s exceeds 15, a decrease in permeability due to an eddy current becomes remarkable because the film thickness becomes large.

[0027]

The present invention will be described in detail by referring to more concrete examples as follows.

(Example 1)

PET substrates were prepared. An Ni base film (a metal sublayer) 19 nm and 37 nm in thickness was formed on each of the PET substrates by the oblique incident evaporation method. After that, Fe-Ni alloy films (soft magnetic metal layers) of various thicknesses which contain about 61 wt % Fe were formed with the Ni base film serving as a cathode conductor and eight types of soft magnetic members were produced as the samples a to h shown in Table 1.

The complex permeability of the obtained eight types of soft magnetic members was measured by use of high frequency permeability measuring instrument made by Ryowa Electronics, Co. (PMF 3000). The measurement results are shown in FIG. 5 to FIG. 12.

[0028]

[Table1]

SAMPLE	SUBSTRATE	METAL SUBLAYER			SOFT MAGNETIC METAL LAYER			p/s
		MATERIAL	THICKNESS (s,nm)	COERCIVE FORCE(Oe)	MATERIAL	THICKNESS (p,nm)	COERCIVE FORCE(Oe)	
a	PET	Ni	19	39.7	61wt%Fe—Ni	105	9.1	5.53
b						147	4.6	7.72
c						188	4.3	9.89
d						214	3.0	11.26
e			37	73		123	10.9	3.32
f						218	6.2	5.89
g						267	5.0	7.22
h						321	4.7	8.68

[0029]

First, the samples a to d whose thickness (s) of the Ni base film is 19 nm will be described.

As shown in FIG. 5, in the sample a (p/s = 5.53), high permeability of 150 or so is obtained at 2 GHz although the real part (μ') of complex permeability begins to attenuate in the vicinity of 800 MHz. The sample a has the thinnest film thickness among all of the samples a to d and it is apparent the attenuation of permeability which occurs in the vicinity of 800 MHz is not caused by an eddy current.

As shown in FIG. 6, in the sample b (p/s=7.72) because the attenuation of μ' begins at a frequency of 1000 MHz (1 GHz) or more and there is no increase in μ'' in the vicinity of this frequency. As a result, tan δ is also suppressed. The sample c (FIG. 7, p/s = 9.89) and the sample d (FIG. 8, p/s = 11.26) also show a similar tendency. However, the resonance frequency of the sample c exceeds 2 GHz, whereas that of the sample d is less than 2 GHz.

As shown in FIG. 5 to FIG. 8, the frequency dependence of μ'' shows a sharp shape with an increase in p/s. At the same time, because the frequency at which a peak value is reached decreases, complex permeability decreases also in a case where the Fe-Ni alloy film is too thick.

In this manner, when a 19 nm thick Ni base film is used, good properties of large μ' and small tan δ ($= \mu''/\mu'$) is exhibited when p/s is 5 to 10 (less than), particularly in the range of 6 to 8.

[0030]

As shown in FIG. 9, although the sample e (p/s = 3.32) shows a high resonance frequency exceeding 2 GHz, μ' begins to attenuate in the vicinity of 650 MHz and μ'' increases at the same time. Therefore, tan δ increases and this is undesirable.

As shown in FIG. 10 and FIG. 11, the resonance frequency of the samples f (p/s = 5.89) and g (p/s = 7.22) decreases somewhat in comparison with the sample e, the value of μ'' on the low frequency side decreases and tan δ is improved.

As shown in FIG. 12, sufficient and necessary properties are obtained in the sample h (p/s = 8.68) although the attenuating frequency decreases somewhat.

From the foregoing, when a 37 nm thick Ni base film is used, good properties of large μ' and small tan δ ($= \mu''/\mu'$) is exhibited when p/s is in the range of 4 to 8.

Incidentally, the same applies also to the case where the thickness of the Ni base film is 19 nm. From FIG. 9 to FIG. 12, however, it is apparent that when the thickness of the Fe-Ni alloy film becomes large, the effect of the Ni base film decreases and the attenuating frequency of μ' decreases.

[0031]

Next, for the samples a, b, c, d, e and g, the B-H curve was determined by a VSM (vibration sample magnetometer). The results are shown in FIG. 15 to FIG. 20. Incidentally, for samples in which only a Ni base film is formed on a substrate, the B-

H curve was also determined. The results are shown in FIG. 13 (film thickness: 19 nm) and FIG. 14 (film thickness: 37 nm).

[0032]

FIG. 15 to FIG. 18 each show the B-H curve of the samples a to d. The coercive force is 10.2 Oe, 5.1 Oe, 3.2 Oe and 2.9 Oe, respectively. Incidentally, it is 39.7 Oe when a 19 nm thick Ni base film is singly used. The p/s dependence of the size of an anisotropic magnetic field also shows a tendency similar to that of coercive force, and it is apparent that the smaller the thickness of the Fe-Ni alloy film, the more susceptible the soft magnetic member will be to the effect of the Ni base film.

[0033]

(Example 2)

A 4 μm thick polyimide sheet was sputtered with Co in a thickness of 150 nm and an about 2 μm thick 60 wt % Fe-Ni alloy film was formed on it. The p/s was 13.3. The permeability of this soft magnetic member at 100 MHz was 50% higher than that of a rolled material (PB Permalloy) of the same thickness.

[0034]

[Effects of the Invention]

As described above, according to the present invention, it is possible to provide a soft magnetic member which is easily produced, together with exhibits high permeability in a GHz band.

[Brief Description of the Drawings]

[FIG. 1] A partial sectional view showing a soft magnetic member in an embodiment of the present invention.

[FIG. 2] A partial sectional view showing the construction of a laminated soft magnetic member obtained by laminating the soft material member shown in FIG. 1 in multiple layers.

[FIG. 3] A view showing a method of manufacturing the laminated soft magnetic member shown in FIG. 2.

[FIG. 4] A view showing another method of manufacturing the laminated soft magnetic member shown in FIG. 2.

[FIG. 5] A graph showing the measurement result of the complex permeability of the sample a in Example 1.

[FIG. 6] A graph showing the measurement result of the complex permeability of the sample b in Example 1.

[FIG. 7] A graph showing the measurement result of the complex permeability of the sample c in Example 1.

[FIG. 8] A graph showing the measurement result of the complex permeability of the sample d in Example 1.

[FIG. 9] A graph showing the measurement result of the complex permeability of the sample e in Example 1.

[FIG. 10] A graph showing the measurement result of the complex permeability of

the sample f in Example 1.

[FIG. 11] A graph showing the measurement result of the complex permeability of the sample g in Example 1.

[FIG. 12] A graph showing the measurement result of the complex permeability of the sample h in Example 1.

[FIG. 13] A graph showing the B-H curve of a sample deposited a 19 nm thick Ni film

[FIG. 14] A graph showing the B-H curve of a sample deposited a 37 nm thick Ni film.

[FIG. 15] A graph showing the B-H curve of the sample a in Example 1.

[FIG. 16] A graph showing the B-H curve of the sample b in Example 1.

[FIG. 17] A graph showing the B-H curve of the sample c in Example 1.

[FIG. 18] A graph showing the B-H curve of the sample d in Example 1.

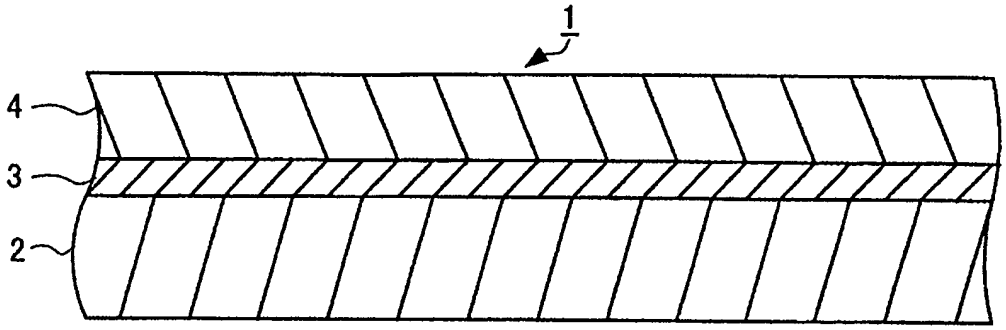
[FIG. 19] A graph showing the B-H curve of the sample e in Example 1.

[FIG. 20] A graph showing the B-H curve of the sample g in Example 1.

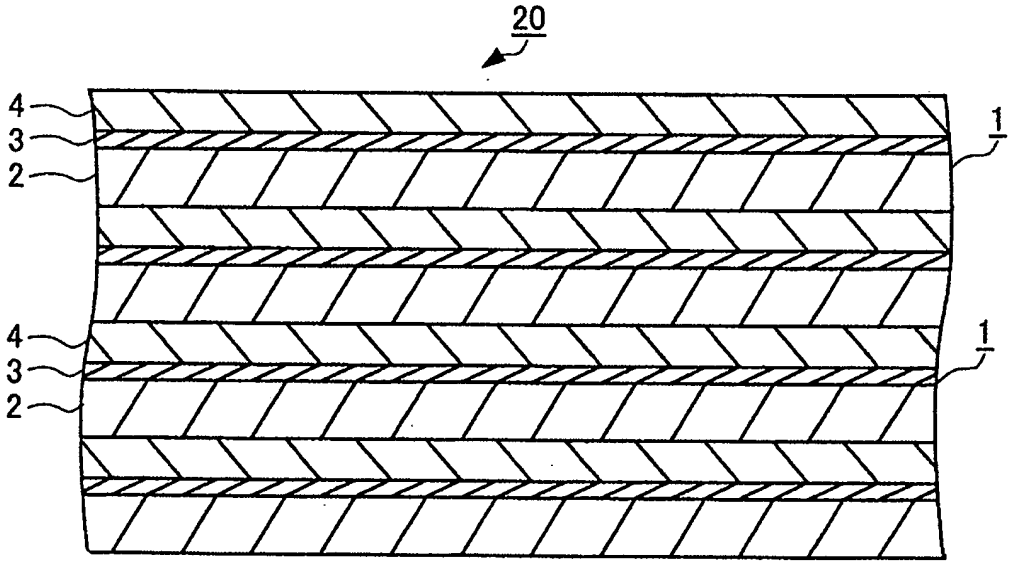
[Description of the Symbols]

1, 10···soft magnetic member, 2···resin film, 3···metal sublayer, 4···soft magnetic metal layer, 5···resin layer, 20···laminated soft magnetic member

[Document] Drawings
[FIG. 1]

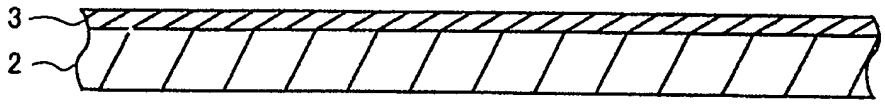


[FIG. 2]

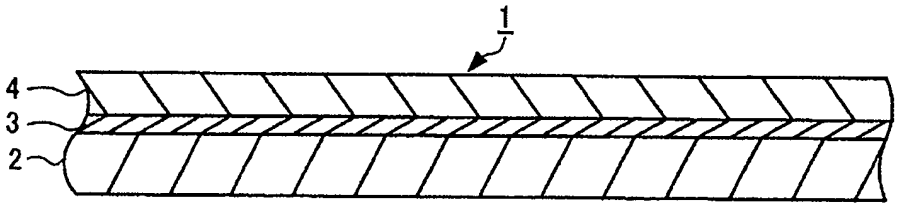


[FIG. 3]

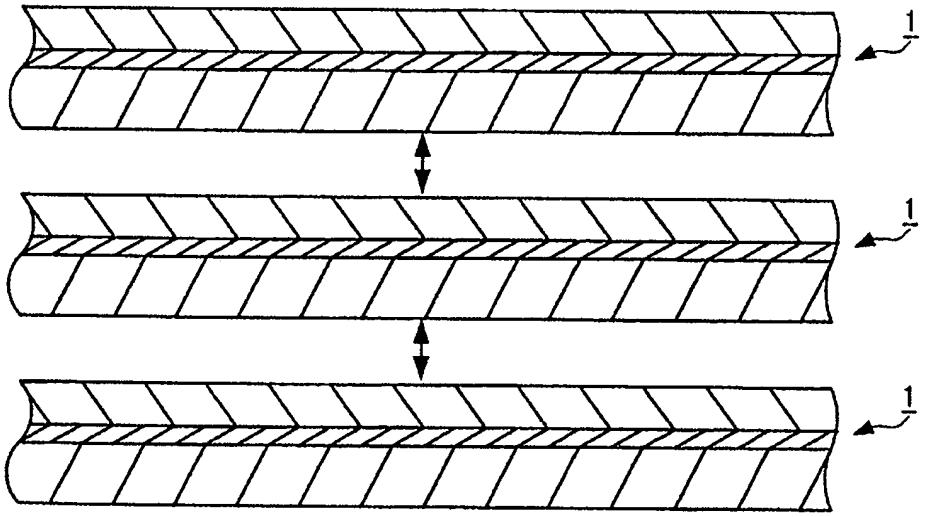
(a)



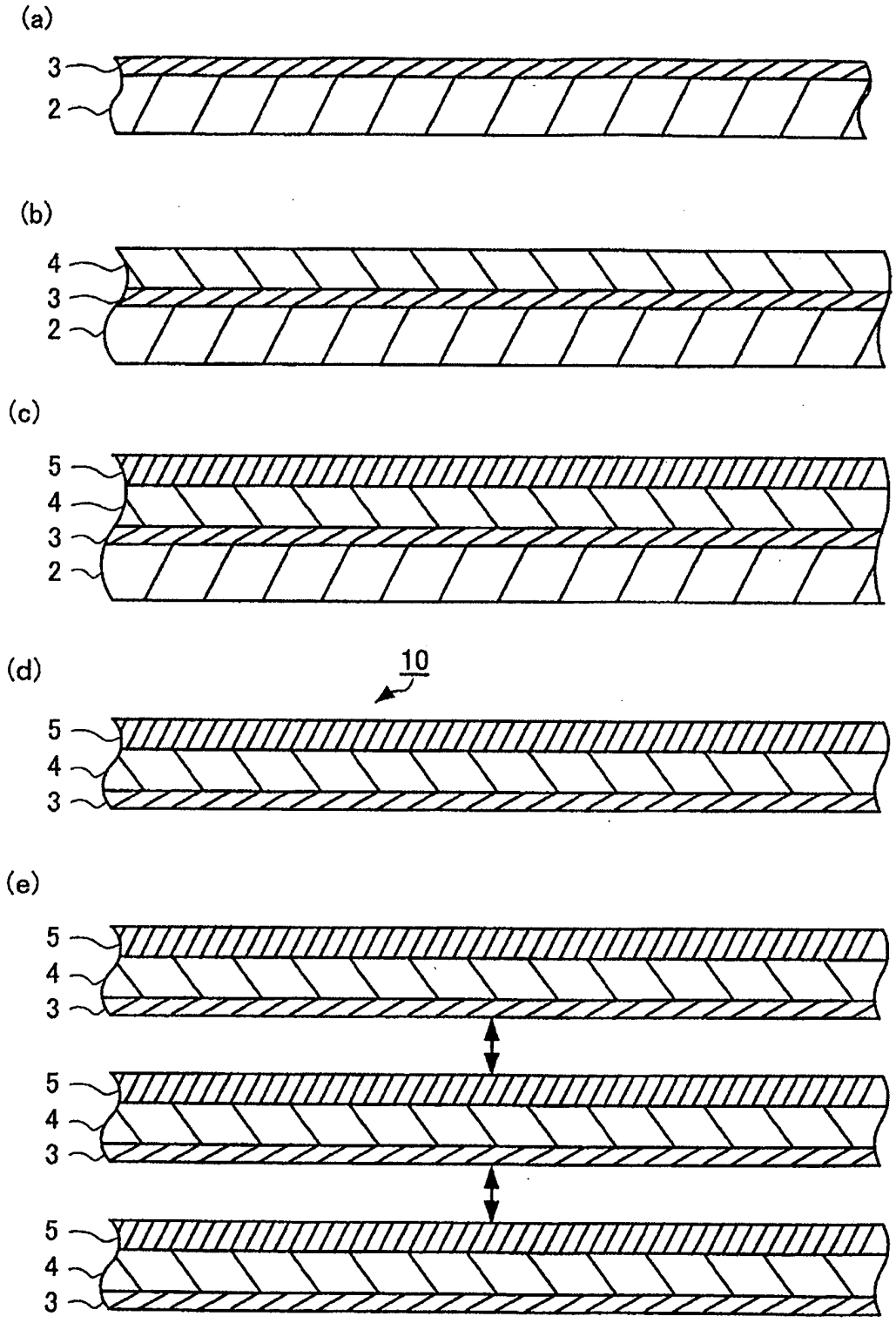
(b)



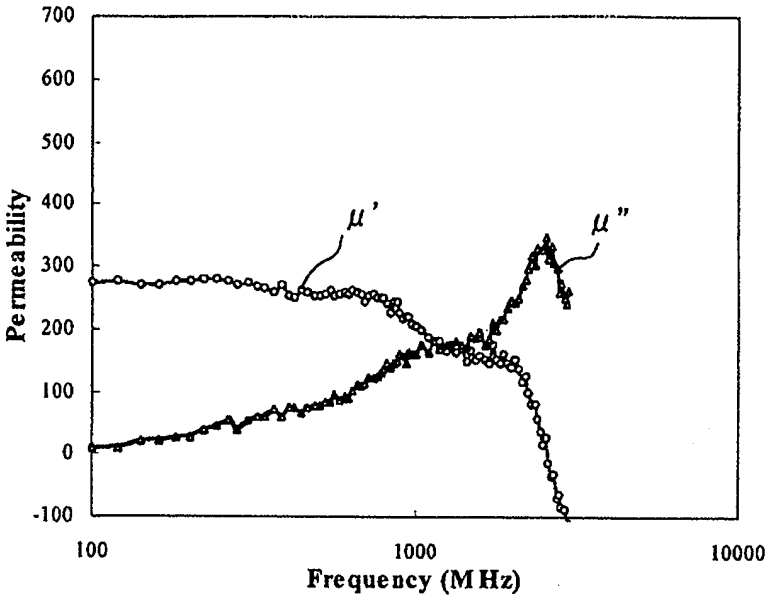
(c)



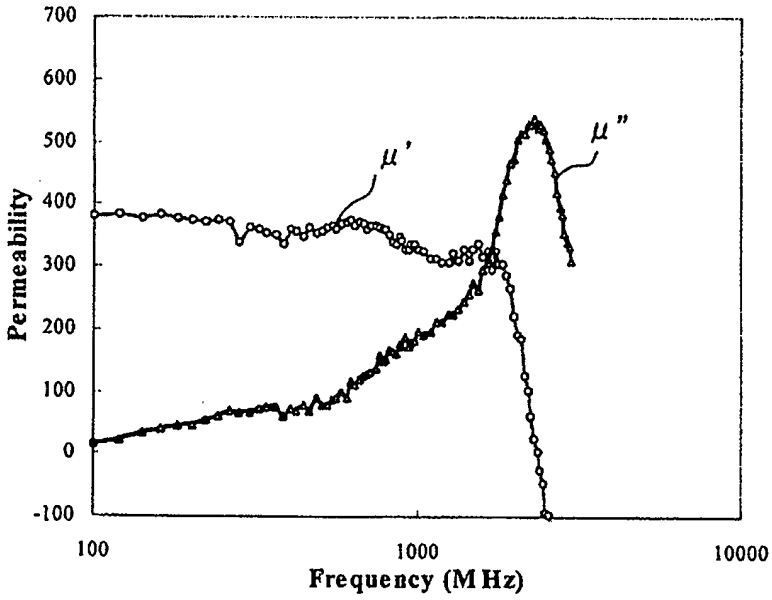
[FIG. 4]



[FIG. 5]


700
600
500
400
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

[FIG. 6]


700
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500
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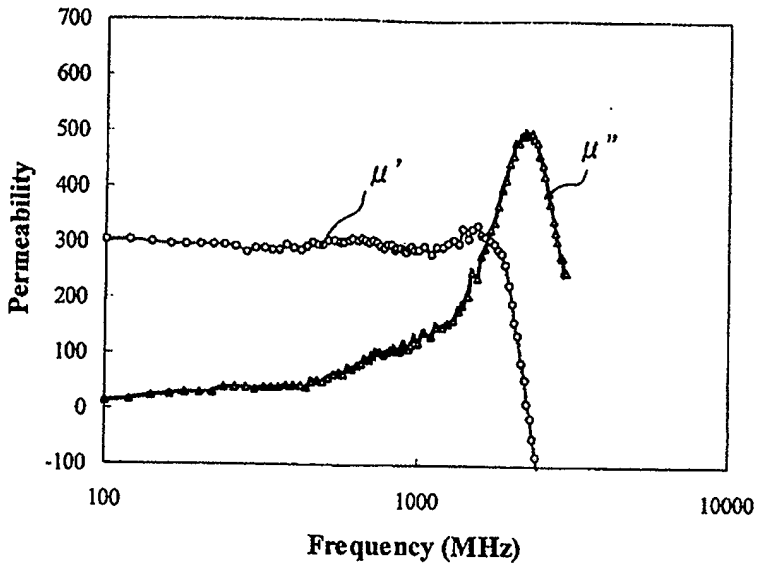
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

[FIG. 7]


700
600
500
400
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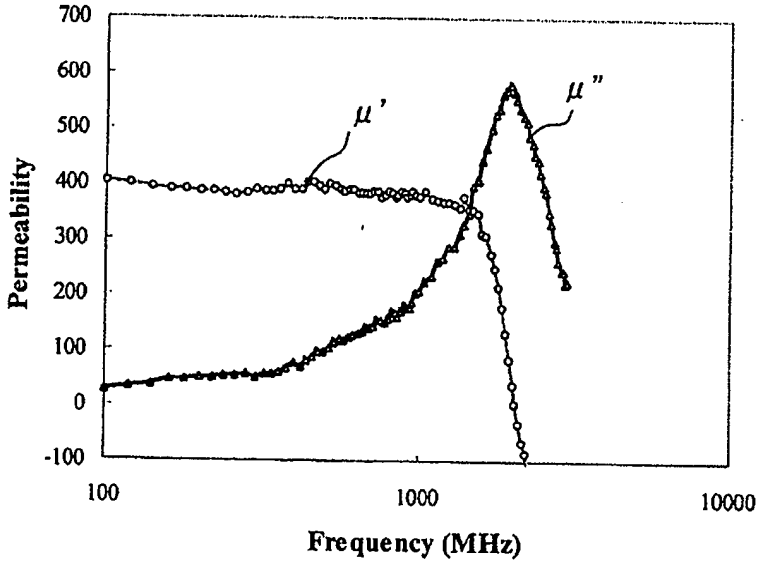
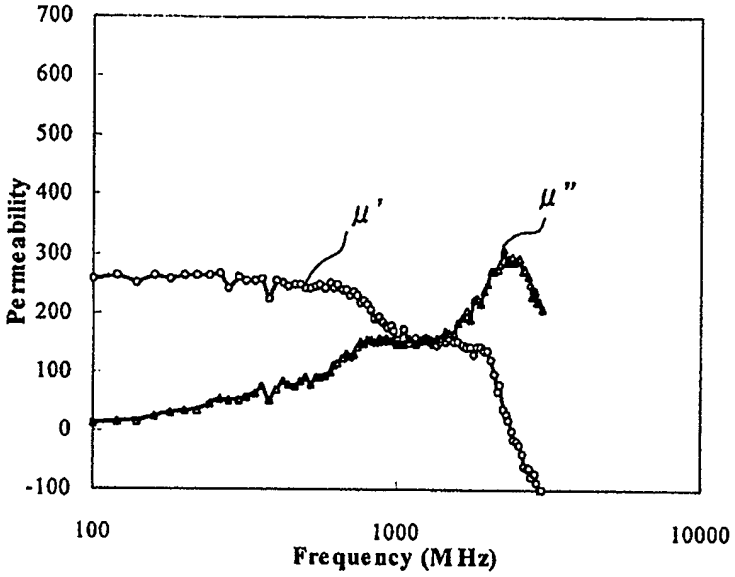
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

[FIG. 8]


700
600
500
400
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

[FIG. 9]


700
600
500
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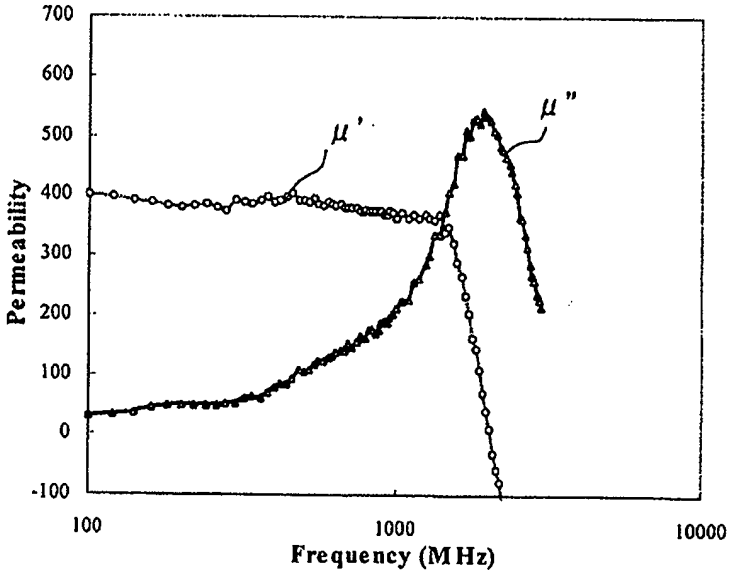
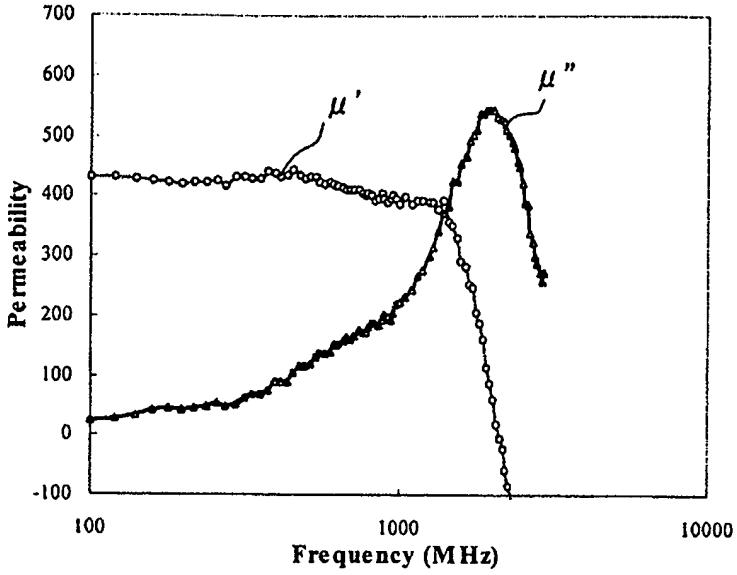
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

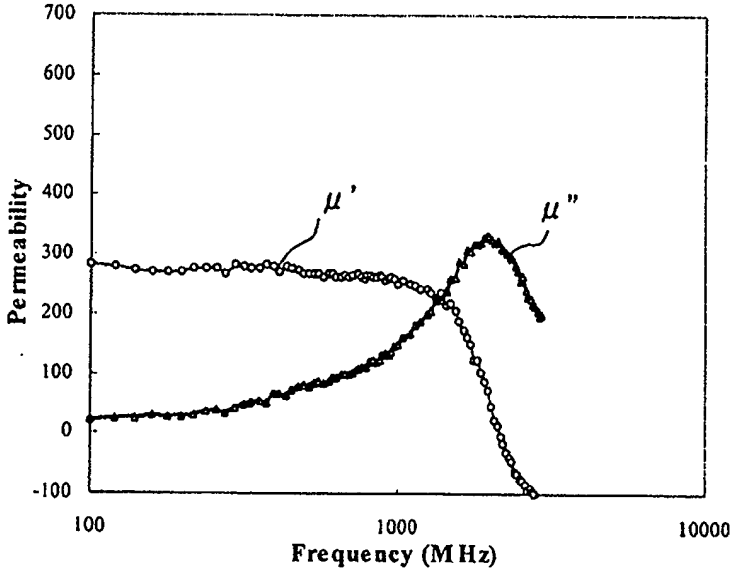
[FIG. 10]


700
600
500
400
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

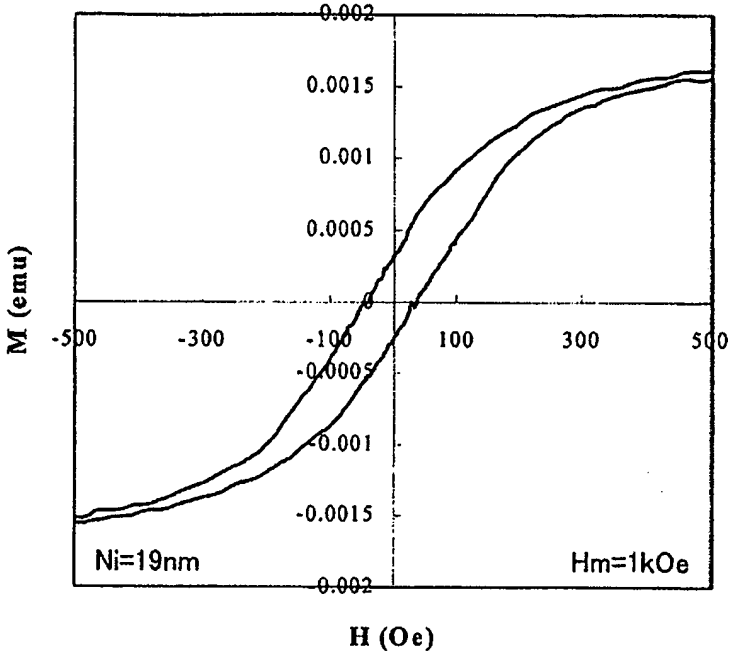
[FIG. 11]


700
600
500
400
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

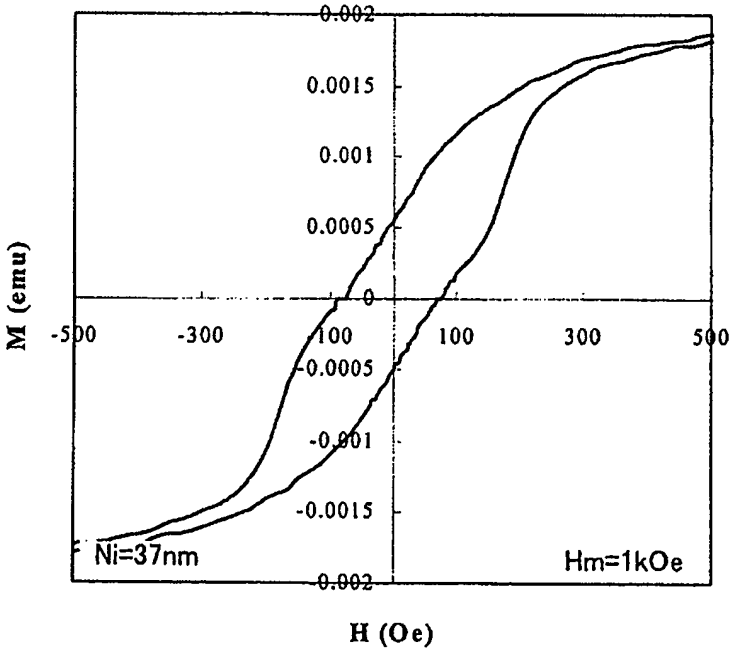
[FIG. 12]


700
600
500
400
300
200
100
0
-100
Permeability
μ'
μ"
100
1000
10000
Frequency (MHz)

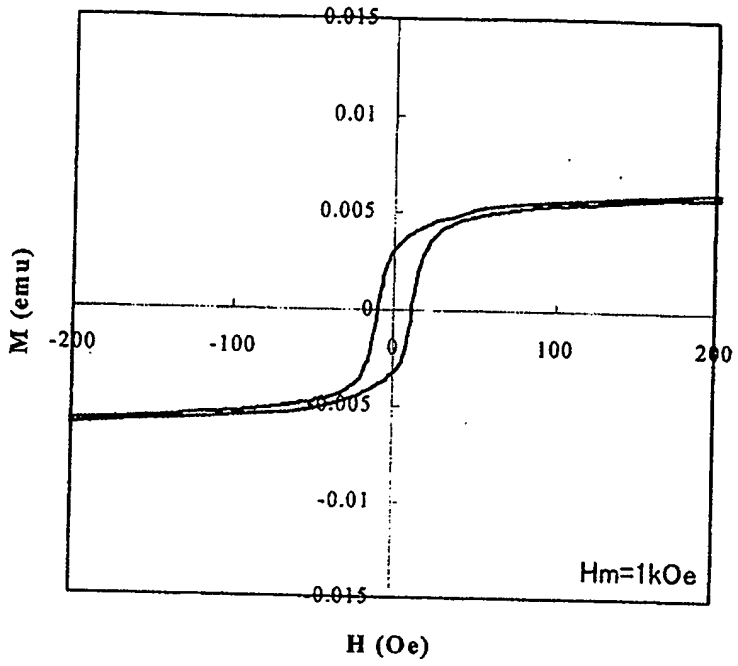
[FIG. 13]


0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-500
-300
-100
100
300
500
M (emu)
H (Oe)
Ni=19nm
Hm=1kOe

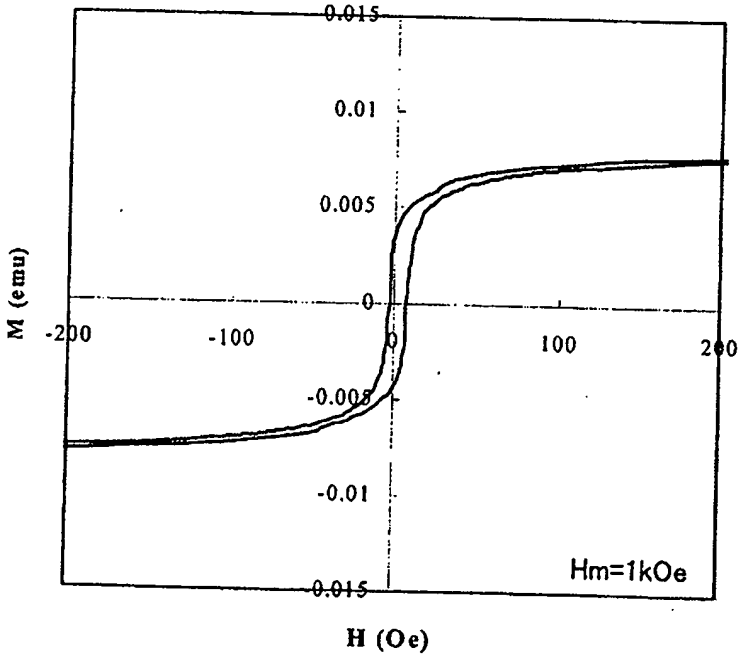
[FIG. 14]


0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-500
-300
100
100
300
500
M (emu)
H (Oe)
Ni=37nm
Hm=1kOe

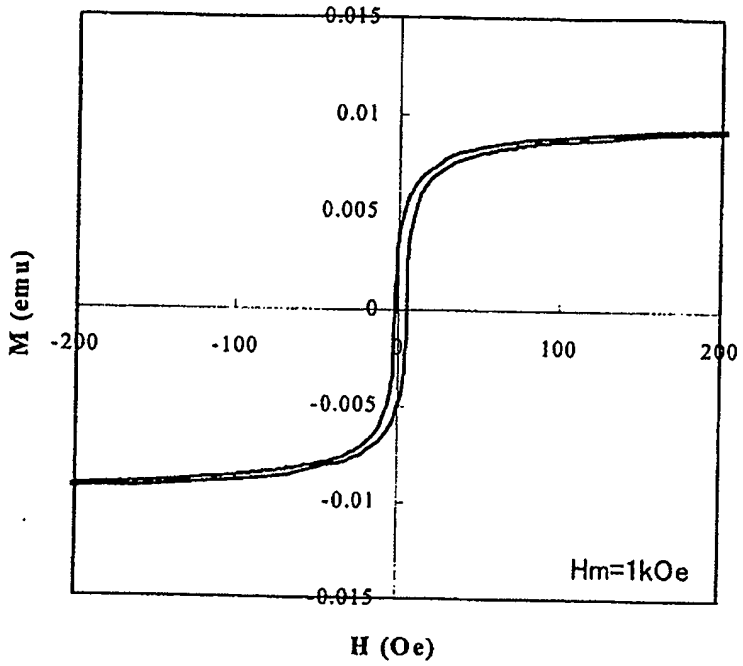
[FIG. 15]


0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-200
-100
0
100
200
M (emu)
H (Oe)
Hm=1kOe

[FIG. 16]


0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-200
-100
0
100
200
M (emu)
H (Oe)
Hm=1kOe

[FIG. 17]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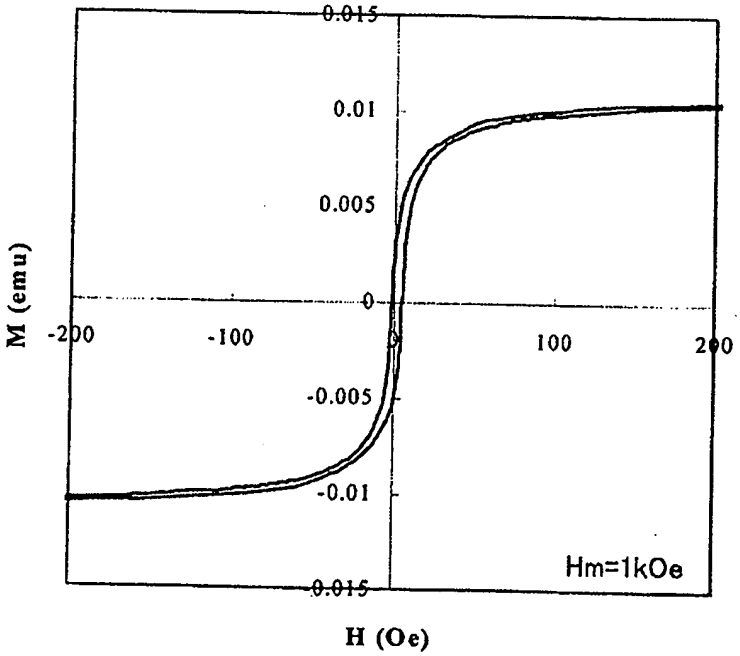
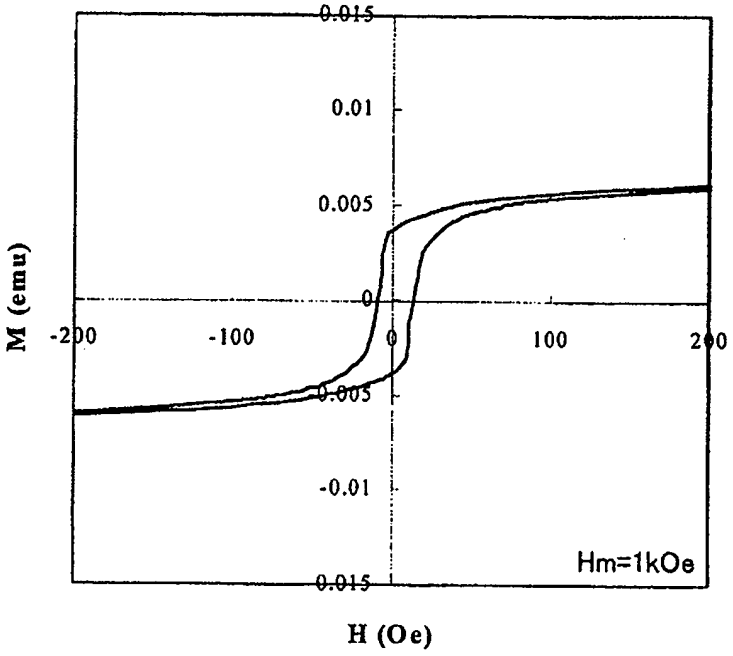
0.01
0.005
0
-200
-100
0
100
200
-0.005
-0.01
-0.015
M (emu)
Hm=1kOe
H (Oe)

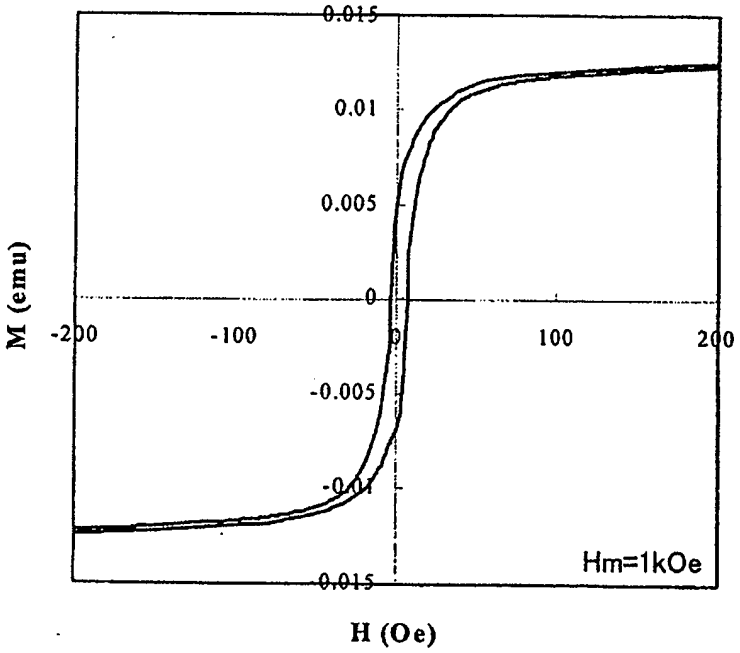
[FIG. 18]


0.015
0.01
0.005
0
-200
-100
0
100
200
-0.005
-0.01
-0.015
M (emu)
Hm=1kOe
H (Oe)

[FIG. 19]


0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-200
-100
0
100
200
M (emu)
H (Oe)
Hm=1kOe

[FIG.20]


0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-200
-100
0
100
200
M (emu)
H (Oe)
Hm=1kOe

[Document] Abstract

[Abstract]

[Object] To providing the soft magnetic member which is easily produced, together with exhibits high permeability in a GHz band.

[Solution] A soft magnetic member 1, comprising: a resin film 2; a metal sublayer 3 disposed on the resin layer 2; and a soft magnetic metal layer 4 disposed on the metal sublayer 3, wherein providing that the thickness of the metal sublayer 3 is denoted by s and the thickness of the soft magnetic metal layer 4 is denoted by p, then the relationships hold: $5 \leq p/s < 10$ and $0 < s < 100$ nm.

[Selected Figure] FIG. 1